Radio-Electronics

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JUNE 1988

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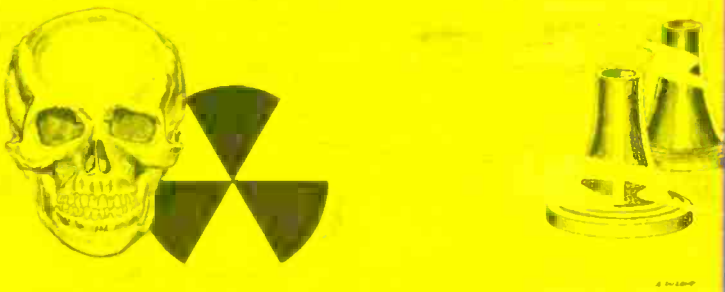

HANDHELD DETECTOR SENSES ALPHA, BETA, GAMMA AND X-RAY RADIATION.

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Vol. 59 No. 6

BUILD THIS

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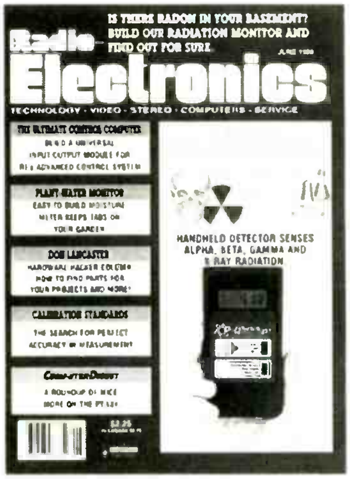
DEPARTMENTS

PAGE 85

PAGE 57

AND MORE

ON THE COVER



Chernobyl and Three Mile Island are not just scary headlines from faraway places—a nuclear accident can affect *all* our lives. Maybe your neighborhood is home to a nuclear power plant, or you worry about radiation that might be emitted by common household objects. Since we can't see or feel the radiation that could be so dangerous, how can you know if there is cause for alarm? You can find out by building the Geiger counter we present on page 41. With it you'll be able to test radiation levels, detect nuclear-plant leaks by monitoring radiation levels, and even sound an alarm if the level is abnormally high. Gain knowledge—and peace of mind—by building our radiation monitor.

COMING NEXT MONTH

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Applications using the universal I/O module.

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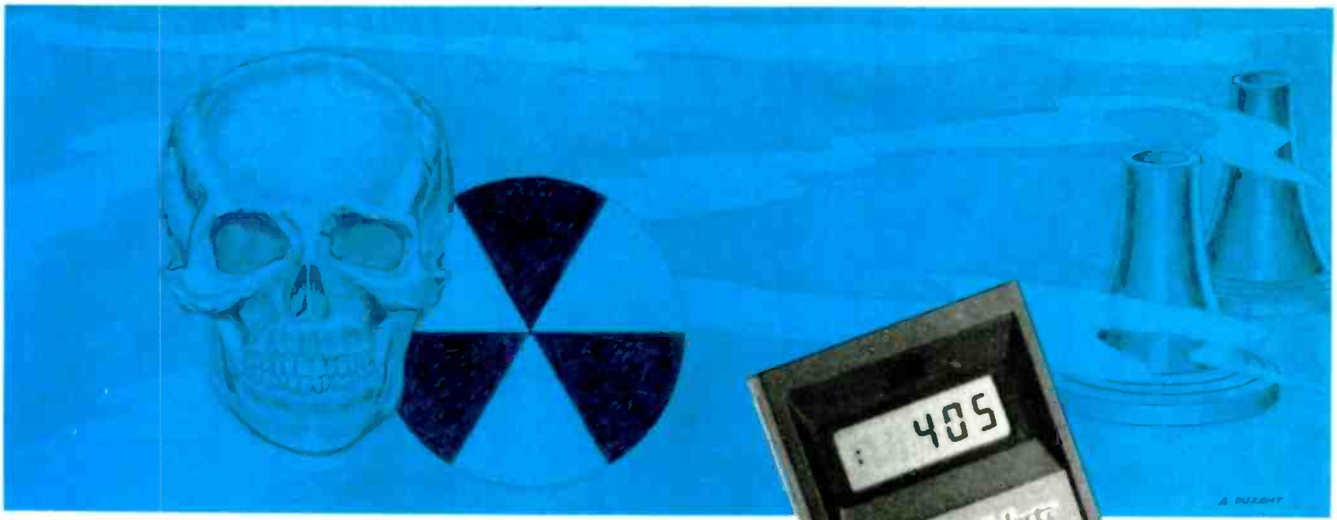

RADIATION MONITOR

This hand-sized Geiger counter is so sensitive it can measure the radiation from a ceramic drinking cup.

JOE JAFFE, DAN SYTHE, AND STEVE WEISS

HAVE YOU EVER DRIVEN PAST A NUCLEAR power generating plant and wondered whether it was leaking radiation? Is there radioactive radon in your basement? When the Chernobyl nuclear plant exploded in April, 1986, and the Three Mile Island plant almost had a meltdown in March, 1979, did you wonder if any of the radiation was coming your way? If you have a luminous watch dial that glows in the dark, is it giving off radiation? Did you know that common items found in a home emit small amounts of ionizing radiation?

Construct your own Geiger counter and you will find the answers to those questions and many more. With a Geiger counter you can reassure yourself that radiation levels in your area are normal. You can detect nuclear-plant radiation leaks by monitoring changes in radiation level, and even sound an alert if the level is abnormally high. You can network with your friends who have similar instruments to determine radiation patterns. You can identify items in your home that are radioactive. And you can explore for underground deposits of radioactive materials. In short, if you build a Geiger counter you will learn about radiation, where it comes from, and how it is detected.

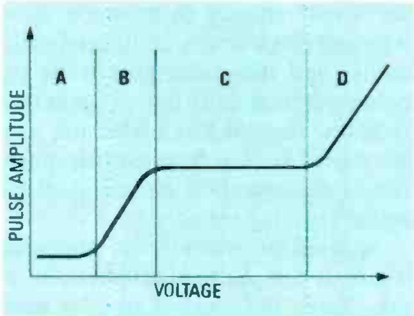

FIG. 1—THE RELATIONSHIP BETWEEN PULSE AMPLITUDE and the electrode voltage of a Geiger tube. Region c, which is the most sensitive to radiation, is called the *Geiger region*.

Measuring radiation

A common characteristic of alpha, beta, gamma, and X-rays is that they ionize the material that they strike or pass through. Therefore, it is possible to measure the amount of radiation by measuring the resulting degree of ionization. One of the first devices used to detect ionization was the electroscope, developed about 100 years ago. In that device, when a gold leaf and its metallic support are insulated from another metallic member and charged to a DC potential of several hundred volts, the gold leaf is repelled. With high-quality insulation, the charge leaks off slowly, but if any ionizing radiation is present the charge leaks off more quickly. Obviously, only relative-intensity measurements are possible.

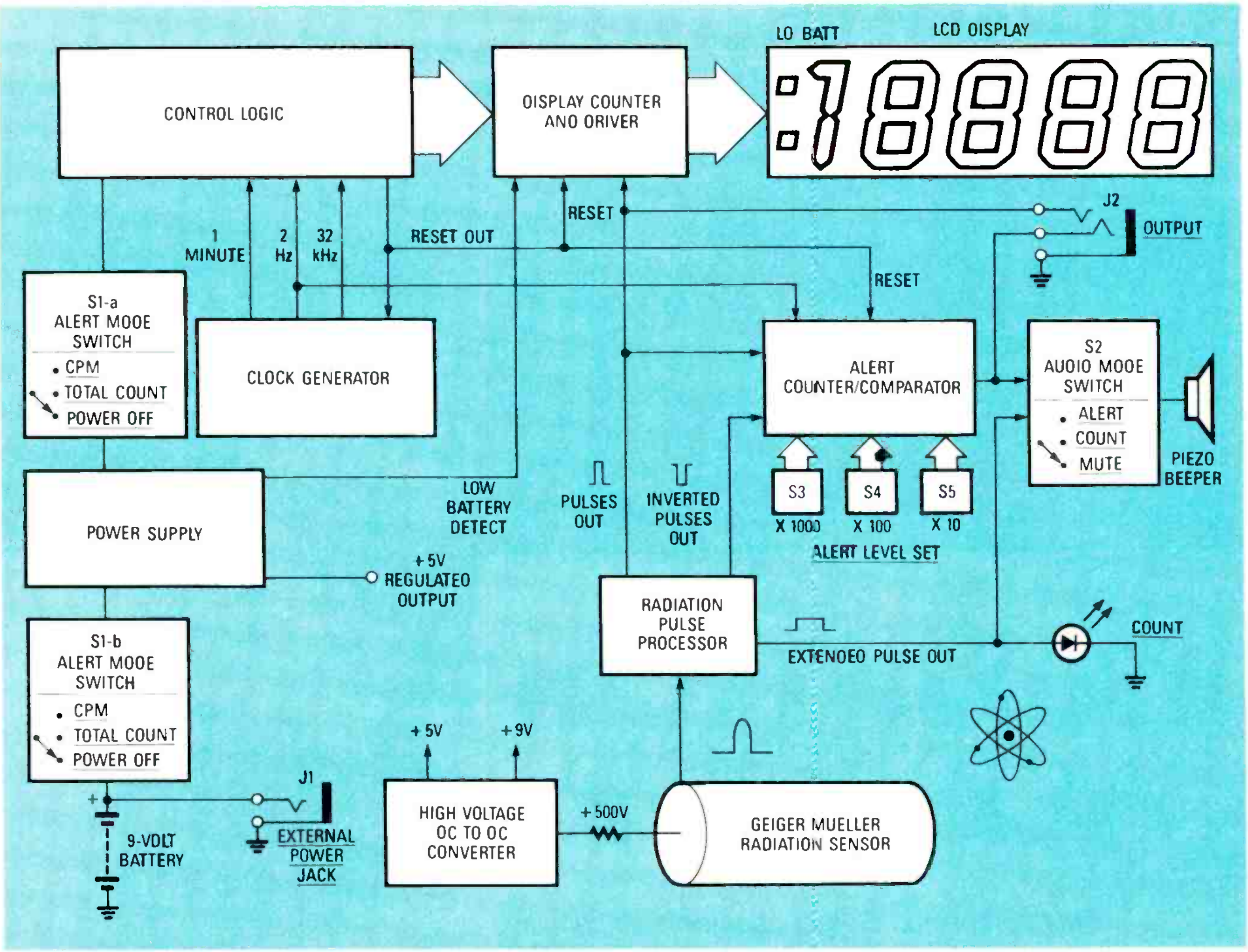

FIG. 2—BLOCK DIAGRAM OF THE RADALERT. The Alert Counter/Comparator can be programmed to sound a beeper when the pulse count exceeds a user-determined value.

The most common sensor used today to detect ionization is the Geiger tube, which consists of an enclosed anode and cathode separated by a mixture of argon, neon, and either chlorine or bromine gases. Usually, the cathode is a thin-wall metallic cylinder sealed at each end with an insulating disk so that the gas is contained. The anode is an axial wire in the cylinder that extends through an insulator. A DC voltage connected to the electrodes creates an electric field within the chamber. A pulse of current is generated when radiation passes through the container and ionizes the gas. The pulses are counted and electronically processed for display in a variety of ways. The relationship between pulse amplitude and electrode voltage is shown in Fig. 1.

A single positive ion and one electron are produced by the initial ionizing event: the collision of an alpha, beta, or gamma ray with a neon or argon gas molecule in the sensor. At low voltages, region A in Fig. 1, the electron moves at low velocity to the central anode and the positive ion moves more slowly to the cathode, where they are neutralized. The detector is rarely operated in that region as extremely small pulses are generated. As the voltage is increased, the velocity and energy of the electron increases. At a specific threshold voltage, the start of region B, there is sufficient energy to produce more ions and electrons by additional collisions, and the pulse amplitude increases dramatically due to gas amplification. Region B is called the *proportional region* because the pulse size is dependent on the energy of the initial ionizing event.

Specialized instruments operating region B can distinguish between alpha, beta, and gamma rays by measuring the pulse amplitudes.

Region C starts when the gas amplification reaches saturation. The pulse amplitudes due to alpha, beta, and gamma rays become essentially equal and increase only slightly with increasing voltage. Region C is the *Geiger region*: it has the highest sensitivity to incoming radiation. Most Geiger counters operate in region C.

When the voltage is increased beyond the Geiger region, the electric field becomes high enough to cause the gas to self-ionize. That occurs in region D and results in almost continuous discharge, which can only be stopped by turning off the voltage. Operation in region D can damage the tube.

The actual threshold voltages for each of the regions depend on the size and shape of the sensor and the configuration of the electrodes.

The thin wall of the Geiger tube allows high-energy beta and gamma rays to pass through and ionize the gas. However, alpha rays have considerably less energy and are blocked by the metallic tube. To detect alpha rays, a very thin mica disk or Mylar

film that is transparent to alpha rays is used in some Geiger tubes to close off one end of the cylinder. That end is called an *alpha window*. The alpha window must point toward the radiation source to detect alpha rays. The range of alpha rays in air is only about 3 centimeters.

Radon

The primary emissions from radon are alpha particles that rapidly dissipate in air. Secondary emissions of beta particles and gamma rays from radon, and from its decay products known as radon "daughters" or "progeny," occur in sufficient quantity to be detected. The EPA has published a booklet on measurement protocols for radon. The simplest technique uses a carbon canister to adsorb radon from the air for weeks or months. At the end of the measurement period the canister is sealed and returned to a laboratory for analysis.

Build a radiation monitor

But waiting for the results of laboratory tests is time-consuming, and if the canister isn't placed in a "hot" spot, false low readings will result. You can do faster measurements by building our radiation monitor, which for simplicity we will henceforth refer to as the *Radalert*.

The Radalert, whose block diagram is shown in Fig. 2, is an extremely versatile Geiger counter that is sensitive to alpha, beta, gamma, and X-ray radiation. It is designed for ease of use by people who want to be better informed about the level of radiation that surrounds them. It also meets the needs of technical, medical, and public-service personnel who require accurate information involving the use, transportation, and storage of radioactive materials. A 4½-digit LCD display provides a direct reading of the number of ionizing events detected by the sensor. (A commercial version of Radalert is currently being tested at a major university laboratory to relate the total counts over extended time periods with calibrated radon levels to determine the time required to get useful results. Preliminary results indicate a 12-hour count may be necessary to detect the increase in background radiation due to low levels of radon and its decay products.)

Two switches allow you to select the operating mode and type of display desired. With switch S2 set to the MUTE position, the COUNT LED visually indicates each ionizing event. When S2 is set to the COUNT position, you will also hear a beep corresponding to each count.

Switch S1 gives you a choice of two display modes. In the CPM (Counts Per Minute) mode, the number of counts detected each minute is displayed on the LCD until replaced by the next minute's count. No count is displayed during the first minute of operation, but the flashing LCD colon tells you that the count is in progress. In the TOTAL COUNT mode, the counts are accumulated and a running total is displayed.

A special feature of our monitor is a user-adjustable alert level. Using the CPM mode, the alert level can be set to a level greater than the normal background radiation. Using the TOTAL

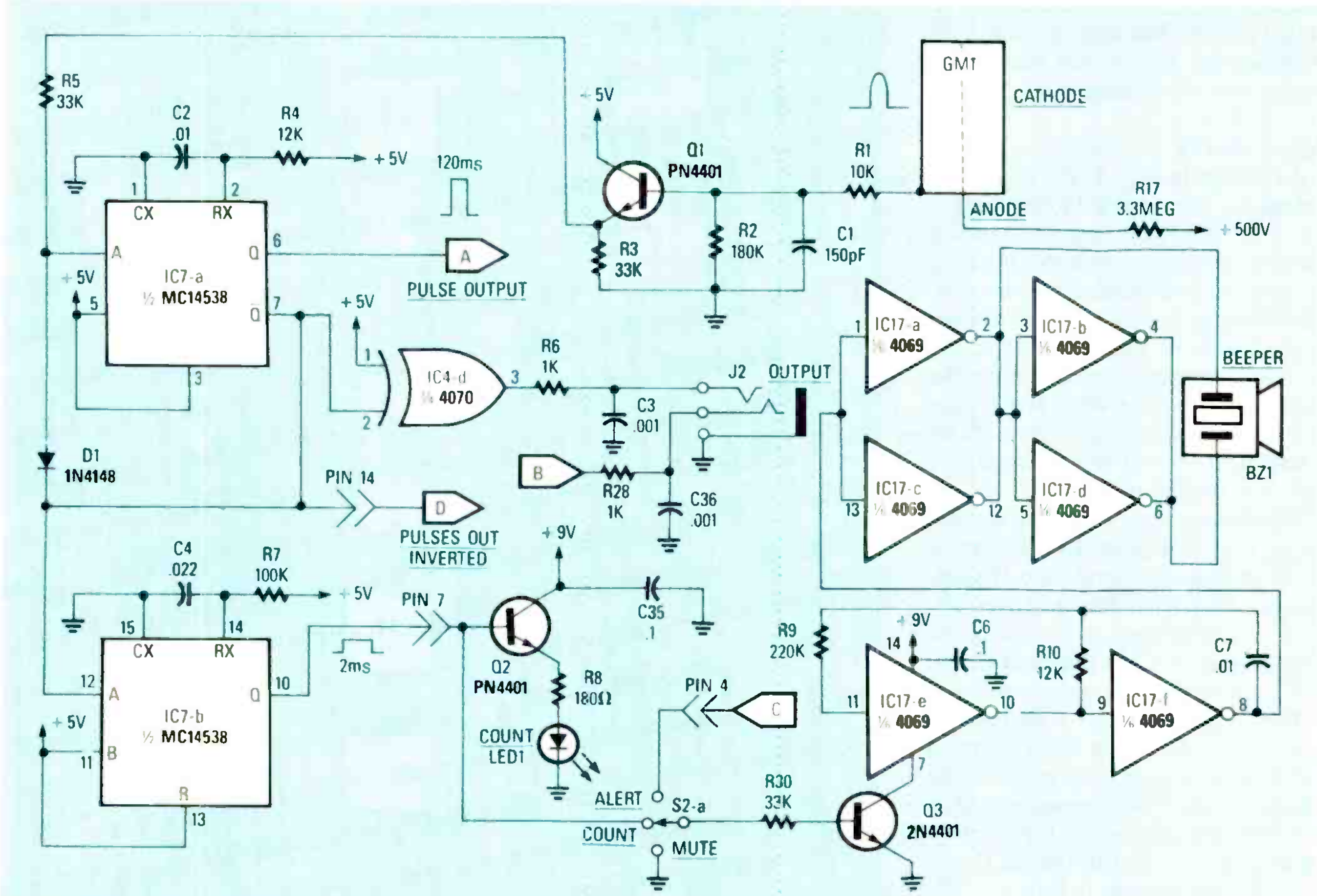

FIG. 3—THIS IS THE CIRCUIT FOR THE GEIGER TUBE and its pulse processor. LED1 blinks in step with each pulse. The beeper also can beep in step with each pulse, and can function as the alert alarm.

COUNT mode you can average the background radiation over long periods when testing for small changes in the background radiation. If S2 is set to its ALERT position, a pulsating beep lets you know when the count reaches the preset alert level.

Portable operation

The monitor is powered by a transistor-radio type 9-volt battery. Very low current drain allows up to 6 months operation before the LO BAT (low battery) indication appears on the LCD display. For continuous 24-hour operation over long periods, the Radalert can be powered by an optional AC adapter connected to EXTERNAL-POWER-jack J1. Notice from Fig. 2 that the battery is not disconnected when the AC adapter is connected to J1. That arrangement permits the battery to automatically take over if the AC powerline fails, thereby assuring uninterrupted measurements. A diode prevents the AC adapter's output voltage from being applied to the battery.

A 500-volt regulated power supply operates the radiation sensor in the Geiger region. The crystal-controlled time-base for the COUNTS PER MINUTE display has an accuracy of 0.005%.

How it works

As shown in Fig. 2, the high-voltage supply is connected to the Geiger tube's anode. Each time an ionizing particle or photon penetrates the tube it creates an avalanche of current. The current pulse is detected and shaped by the Radiation Pulse Processor, and then sent to the counter sections of the display and alert circuits. The Radiation Pulse Processor also provides an extended pulse to drive the COUNT LED and the Piezo Beeper.

The Clock Generator produces the timing signals required by the Control Logic section to operate the Display and the Display Counter/Driver circuits. Control Logic also resets the Clock Generator, and the Alert Counter/Comparator at the proper times.

The Alert Counter/Comparator section accumulates the radiation counts and compares the count to the setting on the binary-coded switches (S3, S4, and S5). When the level on the counter is equal to the BCD setting, the alert output pulsates at a 2-Hz rate to drive the Piezo Beeper when the Audio Mode Switch (S2) is in the ALERT position.

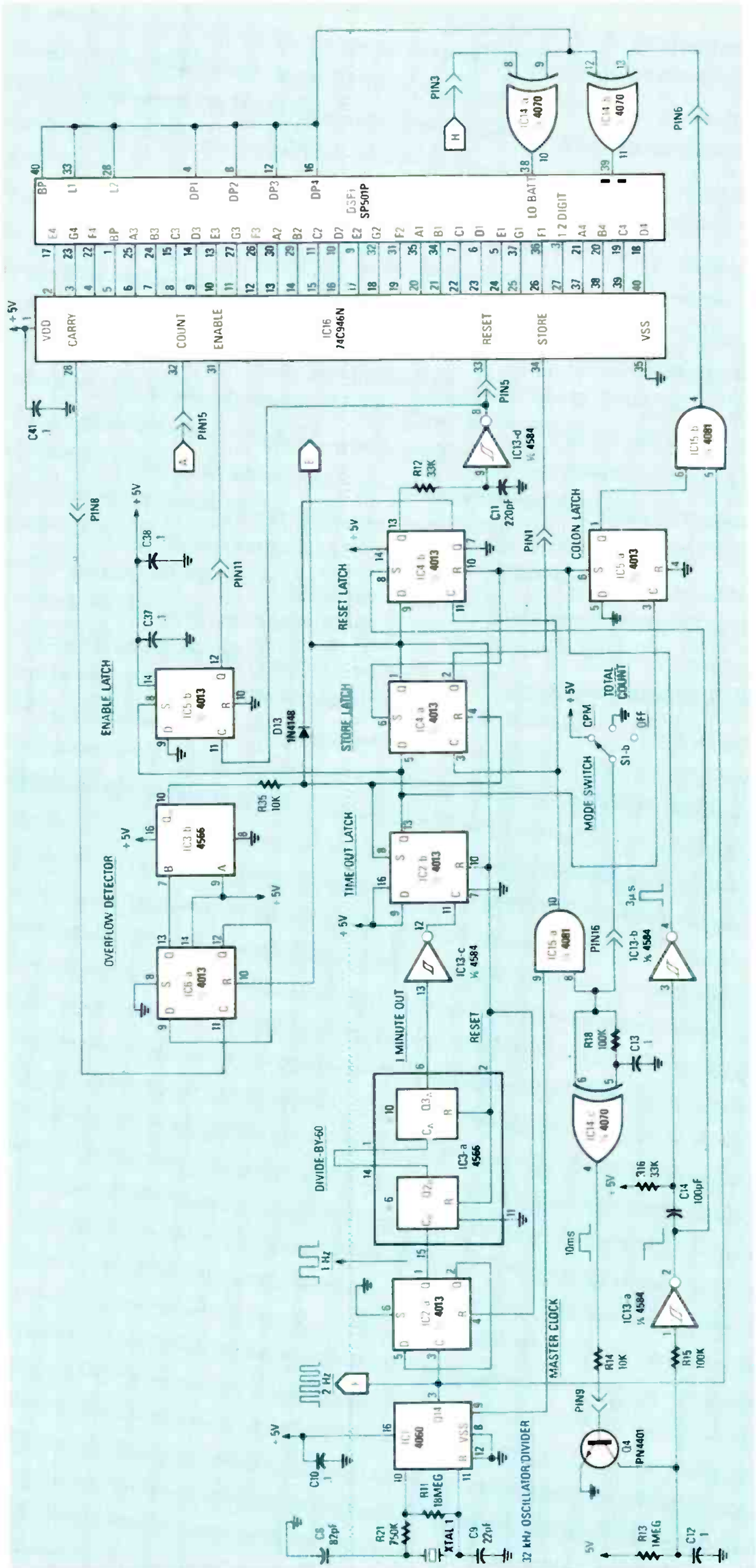

FIG. 4—THE CONTROL LOGIC. A 32-kHz master clock is divided down to provide the one-minute timing for the counts-per-minute function.

PARTS LIST

All resistors are 1/8-watt, 5%, unless otherwise noted.
R1, R14—10,000 ohms
R2—180,000 ohms
R9, R33—220,000 ohms
R3, R5, R12, R16, R30—33,000 ohms
R4, R10—12,000 ohms
R6—1000 ohms
R7, R15, R18—100,000 ohms
R8—180 ohms
R11—18 megohms
R13, R20—1 megohm
R17—3.3 megohms, ½ watt
R19—2.2 megohms
R34—47,000 ohms
R21—750,000 ohms
R31, R32—100 ohms
R22—4700 ohms
R23—1 ohm
R24—510,000 ohms
R25, R26—3.9 megohms
R27—390,000 ohms
R28—1000 ohms
R29—10 megohms
RN1, RN2—220,000 ohm × 6 resistor network
All capacitors rated at least 15 volts, unless otherwise noted
C1—150 pF, 5%, polyester
C1, C11—220 pF, 5%, polyester
C2—0.01 μF, ceramic disc, type X7R
C3, C10, C15, C19, C28, C33, C34, C36—0.001 μF, ceramic disc
C4—0.022 μF, ceramic disc, type X7R
C5, C25, C26, C30, C31—not used
C6, C10, C12, C13, C17, C28, C29, C35, C39, C41—0.1 μF, ceramic disc
C7, C29—0.01 μF, ceramic disc
C9—22 pF
C8—82 pF
C14—100 pF
C16—0.022 μF
C18, C37—47 μF, electrolytic
C20, C21, C22, C23, C24—0.0047 μF, 1KV, ceramic disc
C27—10 μF, tantalum
C32—0.0027 μF, ceramic disc
C38—10 μF, electrolytic
Semiconductors
IC1—4060 oscillator/counter
IC2, IC4, IC5, IC6—4013 dual D flip-flop
IC3—4566 time-base generator
IC7—4538 dual multivibrator
IC8, IC9, IC10—4585 4-bit comparator
IC11, IC12—4518 dual BCD counter
IC13—4584 hex Schmitt trigger
IC14—4070 quad exclusive OR
IC15—4081 quad AND
IC16—74C946 counter/decoder/driver
IC17—4069 hex inverter/buffer
IC18—MAX666 micropower regulator
DSP1—4½-digit LCD display, Seiko SP501P
Q1–Q5—PN4401 transistor
Q6, Q7—MPS6515 transistor
Q8—PN3906 transistor
D1, D10—1N4148 diode
D2—Not used
D3–D6, D12—1N4007 diode
D7–D9—1N5278B diode
D11—1N5819 diode
D13—1N4148 diode
LED1—Light-emitting diode
Other components
B1—9 volt battery
BZ1—piezo-electric beeper, Kyocera KBS-27DB-3T
GM1—Geiger tube, type LND 712
J1—miniature jack
J2—miniature 2-circuit jack
S1, S2—DPDT slide switch
S3, S4, S5—BCD rotary switch, right angle mount
T1—DC/DC blocking transformer
XTAL1—32.768 kHz crystal, watch type
Miscellaneous: Samtec 16-pin male and female connectors, cabinet, printed-circuit materials, wire, solder, cabinet, etc.
Note: The following components are available from International Medcom, 7497 Kennedy Rd., Sebastopol, CA, 95472:
T1, $3.75; DSP1, $10.00; set of two double-sided, plated through printed-circuit boards, $16; GM1, $45. Add $1.00 for shipping and handling for those components. California residents must add appropriate sales tax.
A complete kit, which includes the two printed-circuit boards, the plastic enclosure with custom modifications, labels, all components, hardware, assembly instructions and an operating manual, is available for $149.50 (without battery).
A completely assembled and tested Radalert with an operating manual is available for $225 (including battery).
Add $4.00 for shipping and handling to each Radalert or Radalert kit order. California residents must add appropriate sales tax.
To order the complete kit or the assembled Radalert by Visa or Mastercharge call toll free 1-800-257-3825. In California, call 1-800-255-3825. (Those numbers are for credit-card orders only. For technical information contact International Medcom at the above address.

The circuit

As shown in Fig. 3, the cathode of Geiger tube GM1 returns to ground through Q1's base. The current pulse created in the Geiger tube by a radiation event is about 50 to 75 microseconds long. It pulls up R1, thereby raising Q1's base voltage and turning Q1 on for the duration of the ionizing event. That, in turn, pulls up emitter resistor R3, bringing pin 4 of IC7-a high, which causes the Q output to go high, thereby producing a square wave about 120 microseconds long (the length is determined by the time-constant of R4/C2).

Since $\overline{Q}$, pin 7, is always the opposite of Q, it goes low, pulling the A input low again through D1. The $\overline{Q}$ output to A ensures that the circuitry will continue to count at extremely high radiation levels and not saturate or "jam." The Q output is connected to the display and alert counters. The $\overline{Q}$ output is used by the alert circuit and is also buffered through IC14-d and R6 to the Count Output port (J2's tip), which is the interface to a computer or other data logging device.

One section of IC7, IC7-b, is used as a pulse extender to drive LED1 and beeper BZ1. The pulse width, about 2 milliseconds, is determined by the time-constant of R7/C4.

Beeper BZ1 is driven in a push-pull configuration by two sets of paralleled buffer/inverter gates from IC17. The other two gates of the device are configured as a 3.3-kHz oscillator to match the resonant frequency of BZ1. The oscillator's frequency is determined by the values of resistors R9 and R10, and capacitor C7. The circuit is very efficient, providing a sound pressure level of about 75 dB at 12 inches, with a current drain of 2 mA.

Since the drain is only on for 2 milliseconds per count, that 2 mA averages out to only 1 μA at normal background radiation levels of about 15 counts per minute.

Although LED1 draws 15 mA when it is on, the average current drain is still in the low microampere range. Indicators LED1 and BZ1 are switched by Q2 and Q3, respectively.

LCD display

The 4½-digit liquid-crystal display, DSP1, is the non-multiplexed (direct drive) type. As shown in Fig. 4, it is driven by IC16, a National Semiconductor 74C946, which features 100-microwatt power consumption and leading-zero blanking. It has internal counters for each of the 4 digits and a flip-flop to drive the ½ digit.

The pulses from IC7-a, pin 6 (Fig. 3), are fed to IC16's COUNT INPUT, pin 32. Every negative-going transition clocks the internal counter chain. The STORE pin, pin 34 of IC16, controls the counter latches.

In the TOTAL COUNT mode, pin 34 is low, the latches are in a flow-through state, and counts are actively displayed as they are detected. In the COUNTS PER MINUTE mode, pin 34 is high, and the counter latch outputs are stored. Each minute, CONTROL LOGIC disables the counter, pin 31, while the prior minute count is displayed and stored (pin 34). The counter is then reset to zero (pin 33) to start the count for the next minute.

Clock generator

All timing waveforms are referenced to a 32.768 kHz crystal oscillator built into IC1. That IC has a 14-stage ripple-carry counter that divides the oscillator frequency by two 14 times to give a 2-Hz output at pin 3. The IC2-a flip-flop divides the 2 Hz by two again to furnish a 1-Hz signal to IC3, a 4566 industrial time-base generator that was described in detail in the January, 1988 issue of **Radio-Electronics** (see page 56). The time-base generator divides the 1 Hz, first

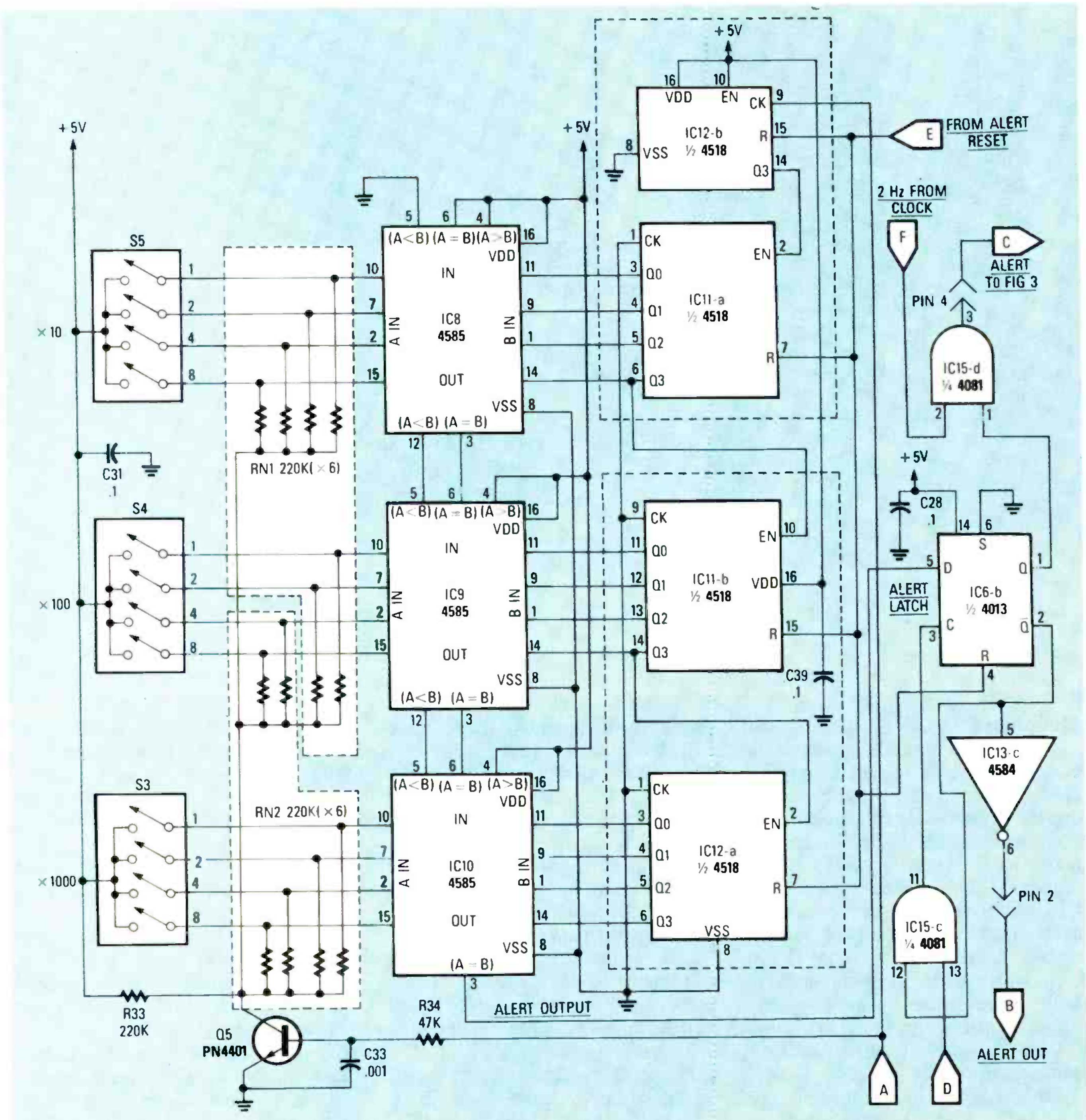

FIG. 5—THE ALERT COUNTER is user programmed through switches S3, S4, and S5.

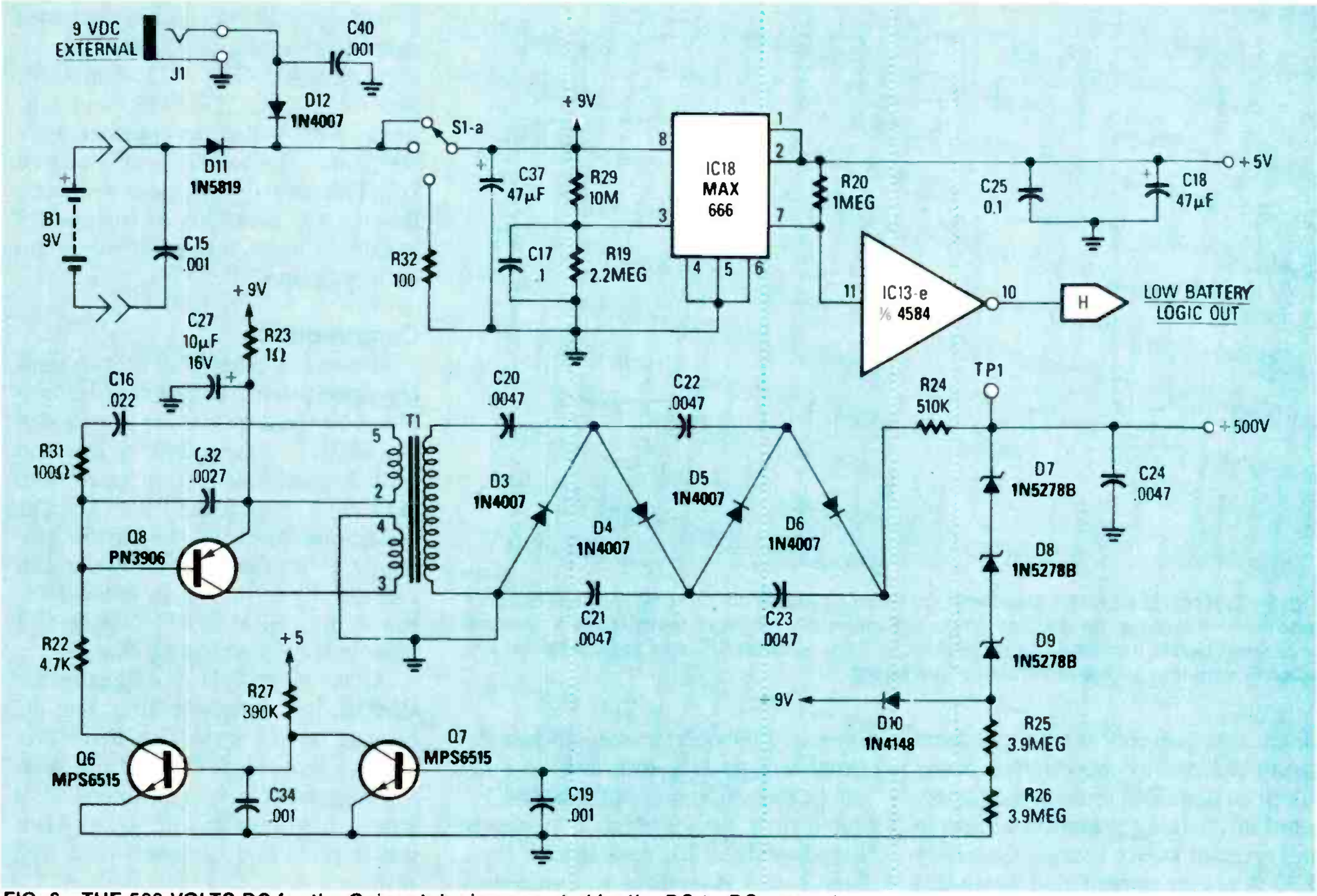

FIG. 6—THE 500 VOLTS DC for the Geiger tube is generated by the DC-to-DC converter circuit consisting of Q6, Q7, Q8, and their associated components.

by six and then by 10, to provide the 1-minute timing signal for the COUNTS PER MINUTE mode. One minute is up when pin 6 goes low; the transition is inverted by Schmitt trigger IC13-c.

Control logic

Refer to Fig. 4. The power up/reset sequence starts when the Radalert is turned on. Capacitor C12 charges through resistor R13, causing IC13-a, pin 2, to go low. Capacitor C14 is momentarily discharged, then recharged through R16. The recharge time is set by the R16/C14 time constant and creates a 3-microsecond power up/reset pulse at IC13-b, pin 4.

Whenever S1 is switched between COUNTS PER MINUTE and the TOTAL COUNT modes, IC14-c, pin 6, goes either positive or negative, with a time delay determined by R18/C13. That section of IC14 is configured as a one-shot that can be triggered on a positive or negative transition, and its output will be high when pin 5 and pin 6 are unequal. The R18/C13 time delay makes them unequal for a very short time, creating a 10-millisecond positive pulse at pin 4 that turns on Q4. The Q4 collector momentarily discharges C12 to re-initiate the power up/reset sequence.

In the COUNTS PER MINUTE mode, critical timing of the IC16 ENABLE, RESET, and STORE functions is implemented by four D flip-flops: IC2-b, the Time Out latch; IC4-a, the Store latch;, IC4-b, the Reset latch; IC5-b, the Enable latch. In the TOTAL COUNT mode, IC15-a inhibits the Master Clock, allowing the radiation count-data from the Pulse Processor to accumulate on the display.

A count of 19999 triggers the overflow detector, freezing the display at that value, and providing a time out signal in COUNTS PER MINUTE mode. In the TOTAL COUNT mode, the 19999 remains on the LCD until S1 is switched.

The colon at the left end of the LCD display flashes at a 2-Hz rate in the first minute of the COUNTS PER MINUTE mode. In the TOTAL COUNT mode, the colon continues to flash as counts are accumulated. A D flip-flop, IC15-a, controls those functions.

Alert counter and comparator

Refer to Fig. 5. Two 4518's, IC11 and IC12, form a chain of four BCD up-counters. Counts from the Pulse Processor feed the least significant digit of the chain, IC12-b, pin 9. The counts are incremented by the ×10, ×100, and ×1000 registers, IC11-a, IC11-b, and IC12-a. Register outputs are compared to the settings of the BCD ALERT LEVEL switches (S3, S4, S5) by IC8, IC9, and IC10. To conserve battery life, comparison is made only as each count is detected. When the alert level is reached, a true alert output is clocked into the Alert Latch IC6-b to energize the beeper at a 2-Hz rate (if S2-a is set to ALERT). The latch then disables any more pulses from clocking through IC15-c.

Power supply

As shown in Fig. 6, the Radalert operates from an internal 9-volt battery, or an external 9-volt power source. Capacitors C15 and C28 are RF-bypass capacitors. External power supply jack J1 does not disconnect the battery when external power is used so that the Radalert will continue to function on battery power if the AC power fails. Diode D11 is a Shottky

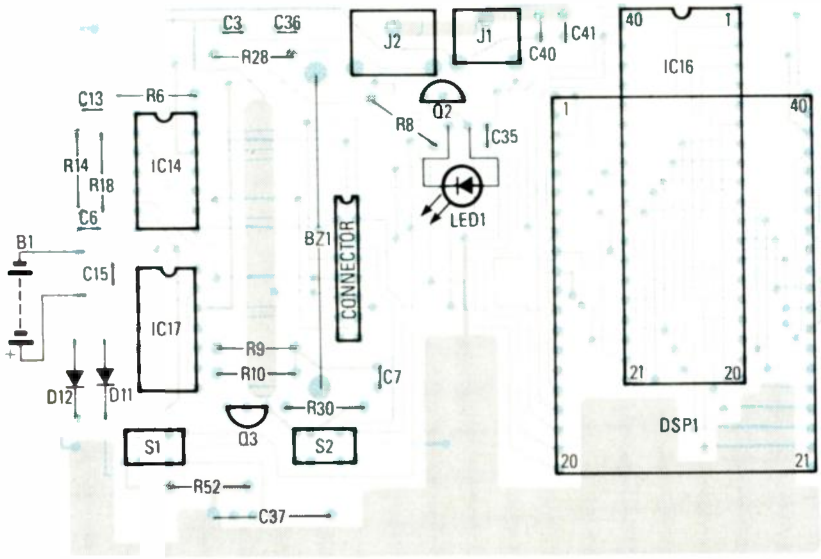

FIG. 7—BOTH THE BEEPER AND THE LCD DISPLAY are on the same board. Take extreme care when handling the display. While not unusually fragile, it nevertheless requires somewhat gentle handling during assembly. Parts IC16, J1, J2, and the connector are actually mounted on the underside of the board.

diode that prevents the battery from being charged by the external power supply. Diode D12 protects the battery from discharging if there is a short in the external power source. Capacitor C37 filters the unregulated 9-volt line that powers the high voltage power supply, LED1, and BZ1.

Switch S1 turns the Radalert on. A MAX666 regulator, IC18, provides regulated 5 volts to the LCD and all the other IC's. That regulator is unusual in that it contains a built-in low-battery detector. The threshold is set by the ratio of R29 and R19. The voltage at pin 3 is compared to an internal 1.3-volt reference. When the input voltage falls to a level that reduces the voltage at pin 3 below 1.3 volts, then pin 7, which is normally held high by R20, goes low. A logic high signal is required to indicate LO BAT on the LCD display, so the state of pin 7 is inverted by IC13-e, an inverting Schmitt trigger.

The high-voltage circuit provides regulated 500 volts at up to 50 microamps, as required by the Geiger tube. It uses a DC-to-DC blocking-oscillator design and closed-loop feedback regulation. Transistor Q8 oscillates at approximately 25 kHz. Transformer T1, in combination with the voltage multiplier formed by capacitors C20, C21, C22, and C23, and diodes D3, D4, D5, and D6, steps up the voltage to approximately 500 volts. The Zener diode chain of D7, D8, and D9 provides feedback through Q7 and Q6, to maintain a constant output-voltage at minimum current drain.

Construction

The unit is assembled on two double-sided printed-circuit boards; templates for those boards are provided in PC Service. Alternately, etched and drilled boards can be purchased from the source given in the Parts List. The plastic enclosure shown in the prototype is available from Bopla Enclosure Systems, P.O. Box 649, Rockville, MD. 20851. (Write for latest price and shipping charges.)

All the IC's used in the Radalert are CMOS, so when stuffing the PC boards avoid building up static charges that might damage the IC's. We suggest wearing a grounded wrist strap when handling the IC's. Also, use a grounded (3-wire) soldering iron.

The location of all components is silk-screened on the pre-drilled printed-circuit boards. If you make your own boards, refer to Figs. 7 and 8 for the parts-placement. Double check the placement and the polarity of diodes, electrolytic and tantalum capacitors, and the orientation of all transistors, IC's, and switches before soldering. Install the BCD ALERT switches, S3, S4, and S5, with their screwdriver slots facing away from the board. And because there is little clearance between the boards, make certain all components except the LCD display are pressed against its board before soldering.

The LCD display is mounted by pressing it against the window in the cabinet, not against the printed-circuit board. Like the IC's, the display is also static-sensitive, so handle it with care.

Because the high voltage section delivers 525 volts DC, do not handle the bottom (high-voltage) printed-circuit board during assembly and testing when the power is on. After testing, an anti-corona conformal coating (such as Dow Corning No. 1-2577) should be is applied to the components and both sides of the

continued on page 102

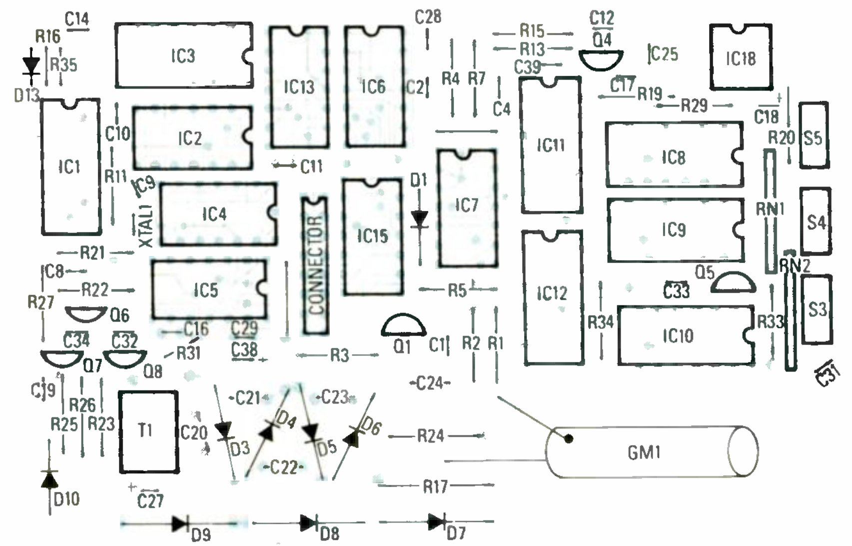

FIG. 8—NOTICE THAT THE BCD SWITCHES that set the alert level mount along the smaller edge of the printed-circuit board. To ensure that their adjustments align with their cabinet cutouts, be sure the switches are pressed against the printed circuit board when being soldered.

RADIATION MONITOR

continued from page 48

printed-circuit board in the high-voltage section. In addition to being a safety precaution, the coating protects against humidity that might cause leakage in the high-impedance regulator circuit.

The two printed-circuit boards mate together through a 16 pin connector. Make sure the high voltage capacitors, C20–C24, are bent over to provide at least a 0.2-inch clearance between them and the top board.

Short leads

Clip the component leads very close in the area of the top board that is adjacent to the Geiger tube. Use care when handling the Geiger tube because both the mica window and the glass evacuation bulb adjacent to the anode connector are delicate. Install the Geiger tube after all other components have been soldered to the bottom board. Connect the Geiger tube's anode—the terminal with the solder lug—to the printed-circuit board through a ¾-inch length of insulated wire. The wire already welded to the Geiger tube is the cathode. The tube is positioned in the cut-out space of the bottom board and is held in place by double-faced adhesive foam on the bottom of the case. Insulate the Geiger tube from the top board with a small piece of *fish paper* or other insulating material rated for at least 1000-volts DC insulation. Make sure the tube is insulated from all components and the PC board. If necessary, trim your cabinet so the boards and switches fit properly.

Testing

Make sure all leads are trimmed close to the printed-circuit board. Look for cold solder joints and solder bridges between traces before turning the power on. Measuring battery drain will usually reassure you that everything is connected properly; the current should be between 100 and 150 microamperes.

Check the regulated 5-volt supply at IC18 pin 2. Check the 525-volt regulated high-voltage supply at the Geiger tube's anode if you have a meter having an input resistance of at least 10 megohms. (A lower resistance will load down the power supply, causing a false voltage drop.)

After testing is complete and voltages are correct, apply the conformal coating previously described.

Using the Radalert

Now that you have the Radalert operating, it's time to put it to work. But that's another story, and it's found in the following article. **R-E**